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1 April 1976 - 30 September 1976

Prepared by F. J. Mauk
and B. R. Williams

Installation and Operation of High Gain
Long Period Seismograph Station

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James T. Wilson, Principal Investigator
(313) 764-6200

William J. Best, Program Manager
(202) 693-0162

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Technical Report Summary
Contract No. F44620-73-C-0060

✓ During this report period, April, 1976, through September, 1976, the White Pine high gain seismograph station was put into routine operation completely calibrated and equated with the other HGLP stations. Personnel from the Albuquerque Seismic Center located the horizontal seismometer transient problem and corrected it. The gain levels and response curves were also set by July. In August, we received a shutdown notice from ARPA and discontinued operation by 30 September 1976.

Continued research in two areas is covered in this report and abstracts of two papers which will be presented at the Seismological Society of America meeting in mid-October. ↗

I. Station Operation

During this report period, HGLP station WPM was recalibrated and put into routine operation. With the assistance of Don Rock and Jack Dorenden from the Albuquerque Seismic Center, difficulties with the Astrodata recorder and backup power systems were corrected. In addition, the source of the transients on the horizontals, which appeared with the installation of the Seismic Center instruments, was located and corrected. Insulating breaker bars of pressed phenolic fiber had adsorbed enough moisture to cause a periodic short across one or more of the coils of both horizontal instruments. The breaker blocks were dried and desiccant added to the tanks before resealing. A series of calibration response curves were also run until the response curves for all three components matched the designated HGLP response curve to within 5% for the period range 10 to 300 seconds. It was found necessary to replace the Ithaco amplifier to match the response curve for the vertical instrument. At the end of July, all instruments were in full operation. The gains on the helicorders were set at 30K.

During the month of August, the record changer mistakenly offset the balance on the helicorders which eventually led to a complete loss of signal on the north-south component and radical attenuation of the other components. Since the Astrodata system and helicorders are driven with the same signal, alteration of the helicorders also led to a failure of the digital recording. Discovery of this difficulty was made only shortly before the ARPA ordered shutdown; thus, the problem remains uncorrected. In addition, all of the helicorder pens were broken during the last two days of operation. The cause is undetermined.

II. Moment-Magnitude Study

Since March, work on the moment-magnitude study using the WWSSN and HGLP networks has been concerned with three aspects:

1. The spectra of four earthquakes recorded on the HGLP stations were analyzed using the FFT and Maximum Entropy methods to access the effectiveness of using this data in source studies.

The preliminary results show that the spectra contain very large side lobes and long period noise, but that the body waves may be less affected by crustal structure at these long periods.

It was concluded that if an independent estimate of seismic moment was made for these four earthquakes, the corner frequency could be picked off the spectra much more clearly and the divergence correction to the body wave amplitude could be isolated and compared to theoretical values.

Data were collected for calculation of the radiation patterns for the four events and the preliminary fault mechanisms were determined using a program developed at Texas Instruments for the WWSSN data. A week long visit to Texas Instruments in Alexandria implemented this program and uncovered an error in an FFT program which gave an artificially high spectral level for the FFT compared to the Maximum Entropy spectral levels. A talk on this work was given at the annual spring meeting of the AGU in Washington, D.C.

2. Methods were investigated for deriving estimates of the seismic moment without the time consuming calculation of the radiation pattern. Brune's AR parameter method was found to be an easy yet fairly accurate way to estimate seismic moment using the area under the surface wave envelope. This procedure was extended to oceanic paths for long period WWSSN records at teleseismic distances. The calibration was done using 12 events with M_0 already calculated. The resulting curve seems accurate to a factor of 2 for moments less than 10^{27} dyne-cm. and factor of 3 for larger events. A set of 15 events in 1974 were analyzed and their moments derived. A presentation of this work will be given at the Eastern Section meeting of the Seismological Society in October in Ann Arbor, Michigan.

3. The third and final aspect of the study was begun in July, 1976, with a trip to the NOAA film chip library in Boulder, Colorado. The seismograms for 8 earthquakes were collected; these events have known static and dynamic source parameters. The relationship of the body wave magnitude M_b to M_0 has been an unexplored area of research. The surface wave magnitude has received more attention, and since one of the few discriminants.

between earthquakes and explosions has been the M_b/M_s ratio, it is felt that M_b may be sensitive to the dynamic source parameters. The idea of duration of the body wave signal from Gutenberg's early works will be investigated in light of recent publications concerned with radiated seismic energy and seismic sources. This work is continuing.

III. The Characterization of Oceanic Rayleigh Group Velocities by Tectonic Regionalization

A new model, based on ocean floor age, for predicting Rayleigh group velocity dispersion for paths through ocean basins was described in Technical Report No. 6, ARPA Contract No. F44620-73-C-0060. During this report period, data has been collected to test the accuracy of the modeling technique for the Pacific, North and South Atlantic, and Indian Basins.

Method of Analysis

The ridge axes are the most prominent Rayleigh group velocity perturbation features for the ocean basins (see Figure 3); therefore, seismograms were selected from WWSSN and HGLP stations to maximize the variety of path conditions with respect to these features. Although data has been collected for all of the major ocean basins except the Arctic, only the results from the Pacific have been analyzed during this report period.

Observed Rayleigh group velocities are obtained by applying the Dziewonski and Landisman moving window analysis technique to the digitized vertical seismogram trace. Although in principle the digitized data from the HGLP stations are available, difficulties in obtaining and processing the tapes makes it more convenient to digitize the analog records. All seismograms are digitized and recorded on paper tape using a Hewlett Packard minicomputer system. The paper tapes are then copied to data files in the University of Michigan's main computer for further processing. The velocity data obtained from the moving window analysis are then corrected for mean bathymetry effects and plotted in the usual manner as group velocity versus period.

Predicted Rayleigh group velocities are obtained currently by overlaying each of the eight period-specific group velocity contour maps (see Fig. 3 & Technical Report No. 6) with the great

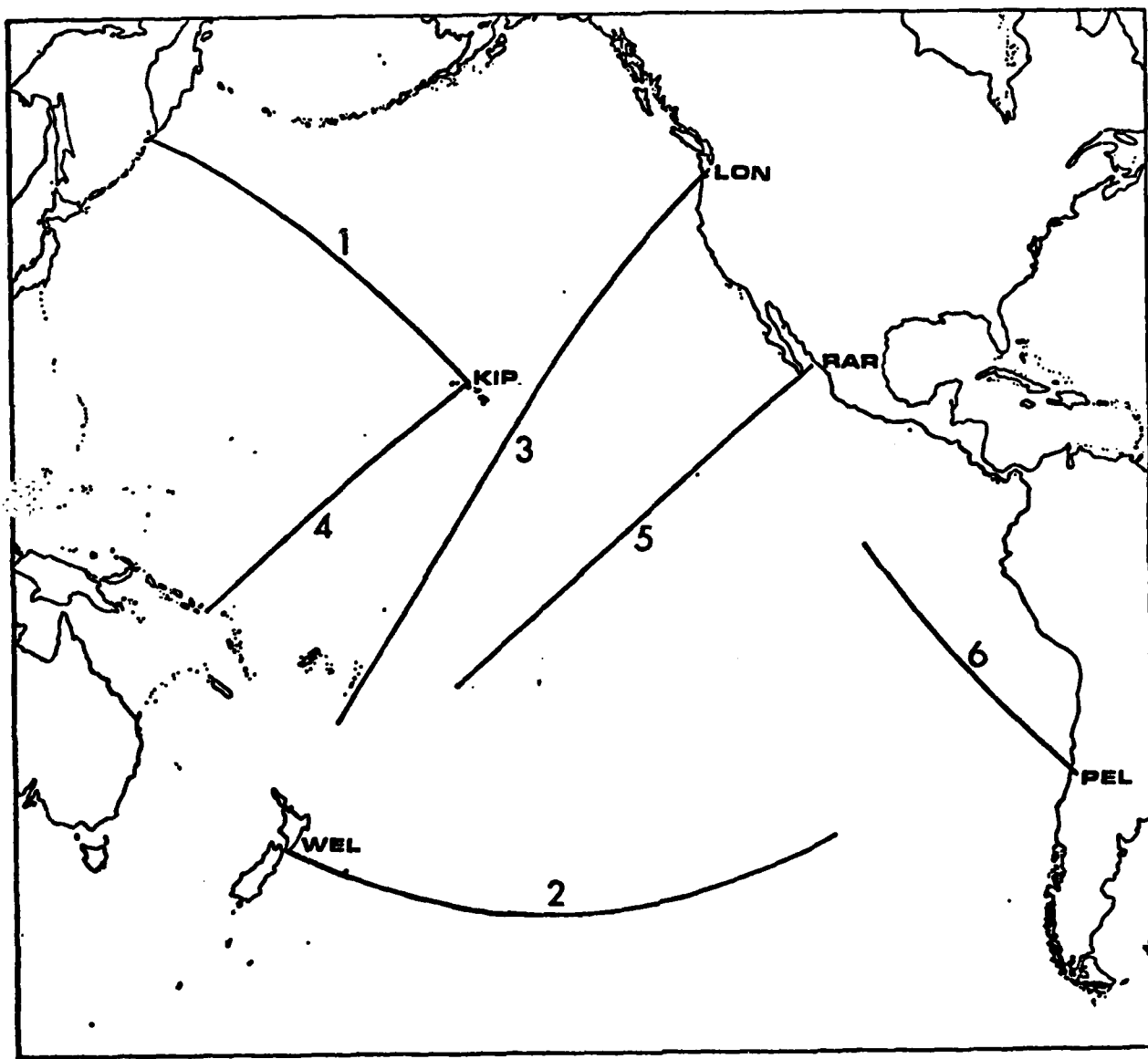
circular route and computing the mean velocities along the path. This is a laborious procedure which will be automated in the future for processing data more easily. Since the contour maps are independent of bathymetry, the predicted group velocity dispersion can be compared directly with the bathymetry corrected observed group dispersion curve for the same path.

Comparison of Observed and Predicted Rayleigh Group Velocity Dispersion in the Pacific Ocean Basin

Six great circle paths across the Pacific basins are illustrated on a Mercator cylindrical conformal projection in Figure 1. The corresponding Rayleigh group velocity dispersion curves are illustrated in Figure 2. The path number and WWSSN station labeled in Figure 1 is repeated in Figure 2 for ease of comparison. In addition, the latitude and longitude of the earthquake and epicentral distance are given on each dispersion curve plotted in Figure 2. The open circles in Figure 2 correspond to the observed group velocities obtained by the moving window analysis of the seismograms. The closed circles correspond to the data corrected for mean bathymetry effects. The curves in Figure 2 are the bathymetry-corrected group velocity dispersion curves for earth structure model 8099 (dashed), model CIT-11A (dotted), Harkrider-Anderson model (dot and dash), and the new tectonic model (solid). The first three models are given for comparison since they have been accepted as reasonable earth structure models for oceanic regions at various times. Since these three have fixed structure, the dispersion character remains fixed for all paths. The tectonic model, on the other hand, has built into it the empirically suggested variability in structure and/or elastic properties as a function of age. The dispersion curve determined from this model is, thus, path dependent and changes according to the ages of ocean floor traversed. Path 1, therefore, which traverses very old ocean floor from the Kurils to KIP has relatively higher velocities than Path 6 from the East Pacific

Rise to PEL. Clearly, however, regardless of the path, the tectonic model consistently predicts the Rayleigh group velocities for the periods from 40 to 90 seconds commonly with residuals less than 0.02 km/sec.

Similar test studies are currently underway for the Atlantic and Indian Ocean Basins.



Pacific Test Paths

Figure 1.

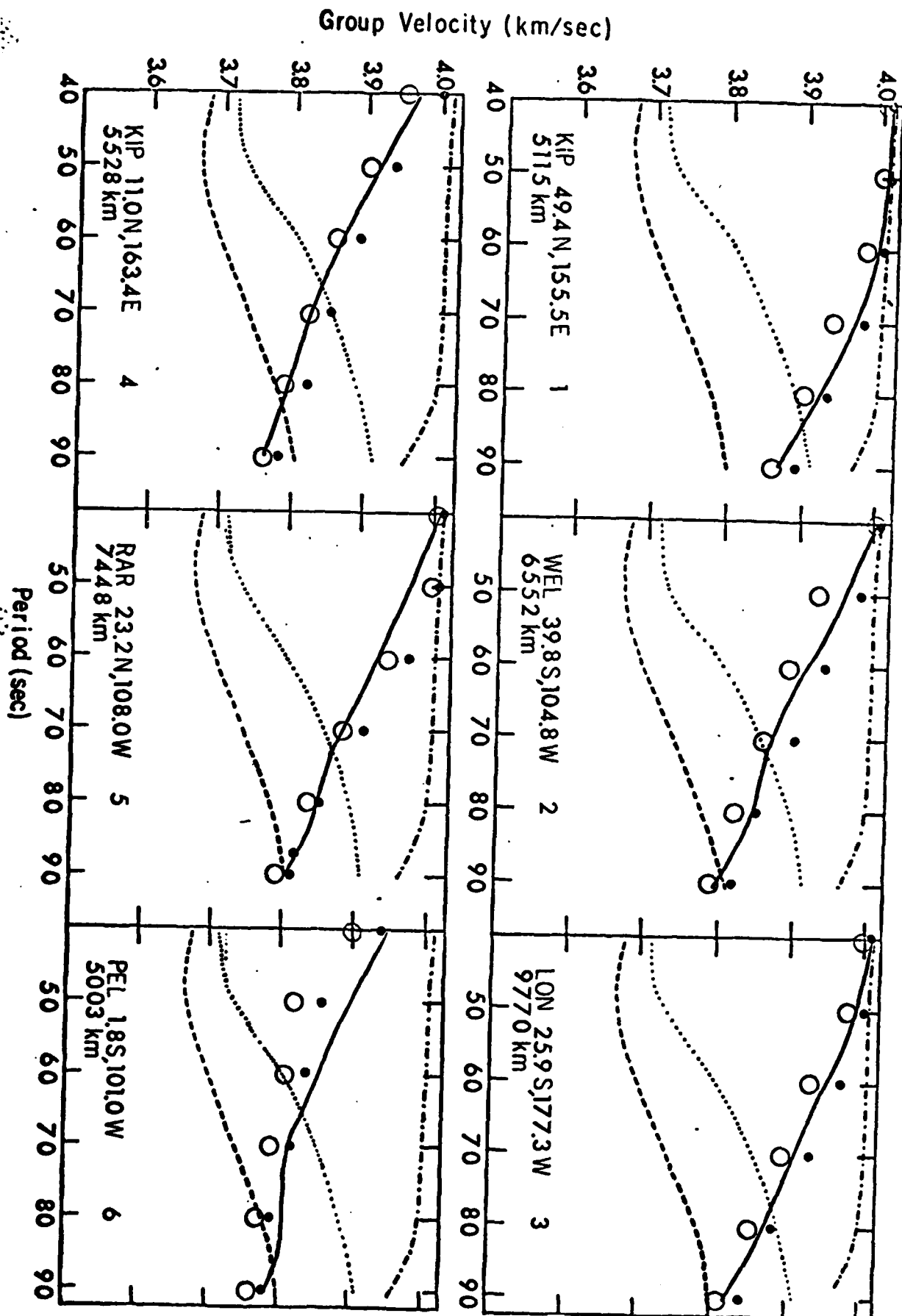


Figure 2.

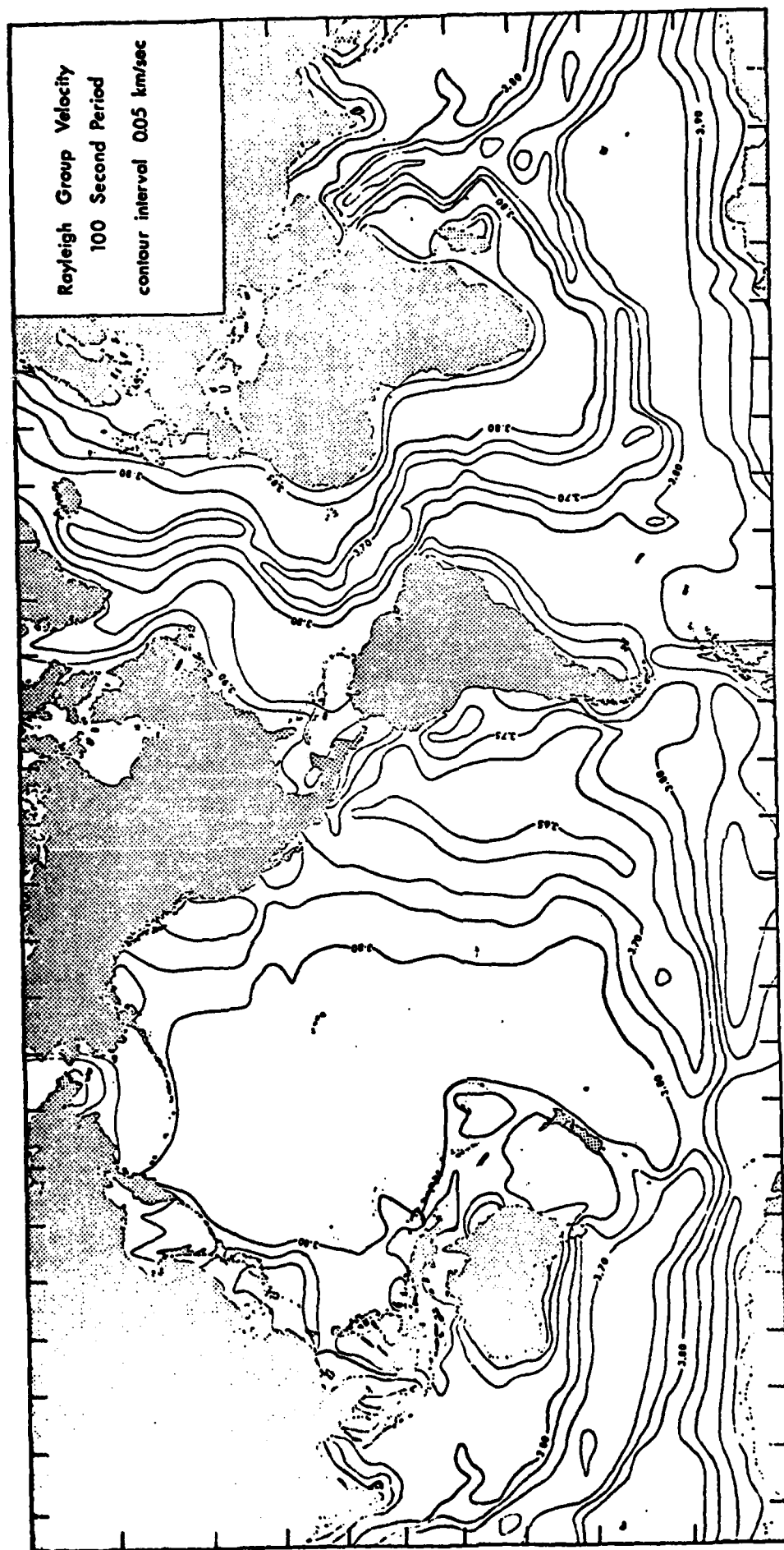


Figure 3.

SEISMIC MOMENTS FROM BRUNE'S AR METHOD
AND DETERMINATIONS FOR INTER-INTRAPLATE
EVENTS

Barbara R. Williams (Department of Geology
and Mineralogy, University of Michigan,
Ann Arbor, MI 48109)

Seismic moments of 20 shallow earthquakes in 1974-1975 with $5.0 < M_s < 8.0$ have been calculated using a modified Brune's AR parameter method. Several major events in this data set are of an intraplate nature, i.e. not on well defined plate boundaries, including the Leeward Is. 1974 event with new $M_0 = 2.2 \times 10^{26}$ dyne-cm, the Utah-Idaho 1975 event with $M_0 = 8 \times 10^{24}$, and the Tadzhik-Sinkiang 1974 event with $M_0 = 1.7 \times 10^{26}$. On an M_0 vs M_s diagram, these data tend to show higher apparent stresses ($n\bar{\sigma} \geq 100$ bars) for the intraplate events, as Kanamori and Anderson (1975) have found in their data. The Brune's AR method has been calibrated using 12 events with independent M_0 estimates that have been recorded on WWSSN long period stations over predominantly oceanic paths. A total of 15 stations in Pacific, Atlantic, and Indian Oceans, at epicentral distances up to 17000 km are used - at least two stations per event. An epicentral distance correction based on a more detailed Q structure than Brune's, as well as an added correction for instrument response must be applied to give a nearly linear M_0 vs AR relation. Aftershocks are the largest source of error and give moment estimates with a factor of 2 error for events with moment $\leq 10^{27}$ dyne-cm and a factor of 3 error with moment determinations $> 10^{27}$ dyne-cm.

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3. Seismology
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RAYLEIGH OCEANIC GROUP VELOCITY DISPERSION: A PREDICTIVE MODEL DERIVED FROM TECTONICS

Frederick J. Mauk (Department of Geology and Mineralogy, University of Michigan, Ann Arbor, MI 48109)

A functional relationship between sea floor age and group velocities of fundamental mode Rayleigh waves for periods from 30 to 100 seconds has been empirically determined. This 10% systematic increase in group velocity with increase in age is used to define a bathymetry corrected age-velocity matrix. Multiplication of this age-velocity matrix and a $5^{\circ} \times 5^{\circ}$ matrix encoded with sea floor age has yielded Rayleigh group velocity contour maps at periods of 30, 40, 50, 60, 70, 80, 90, and 100 seconds for the world's oceans. Comparison between predicted and observed group velocity dispersions using these maps yields velocity residuals consistently less than 0.02 km/sec.

1. Fred Mauk
Dept. of Geology
and Mineralogy
University of Mich.
Ann Arbor, MI 48109
2. Seismological Society
Eastern Section Meeting
3. Surface Waves
4. No
5. No
6. 0%
7. Department of Geology
and Mineralogy
University of Mich.
Ann Arbor, MI 48109
8. P.O. number requested